

Astrometric calibration of all-sky camera for aircraft spotting and meteor observations

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Introduction

All-sky cameras are a staple of astronomical and SLR observatories. They are environmental awareness tools, showing e.g. cloud presence, illumination conditions, and the laser beam direction. For actual positional tasks, these cameras require a star calibration to correct for their orientation, internal misalignments, and the optical behaviour of the lenses. This accomplished, they become precise measuring instruments that find new applications.

Model and Implementation

Conceptually identical to a mount pointing model, the astrometric calibration transforms *plate* coordinates to *celestial* coordinates.

It takes into account:

- Camera horizontal orientation and tilt
- Optical axis alignment, projection and distortions
- Internal sensor misalignment

A popular model in meteor astronomy was given by Borovička [1], later reformulated by Barghini [2] to improve parameter estimability.

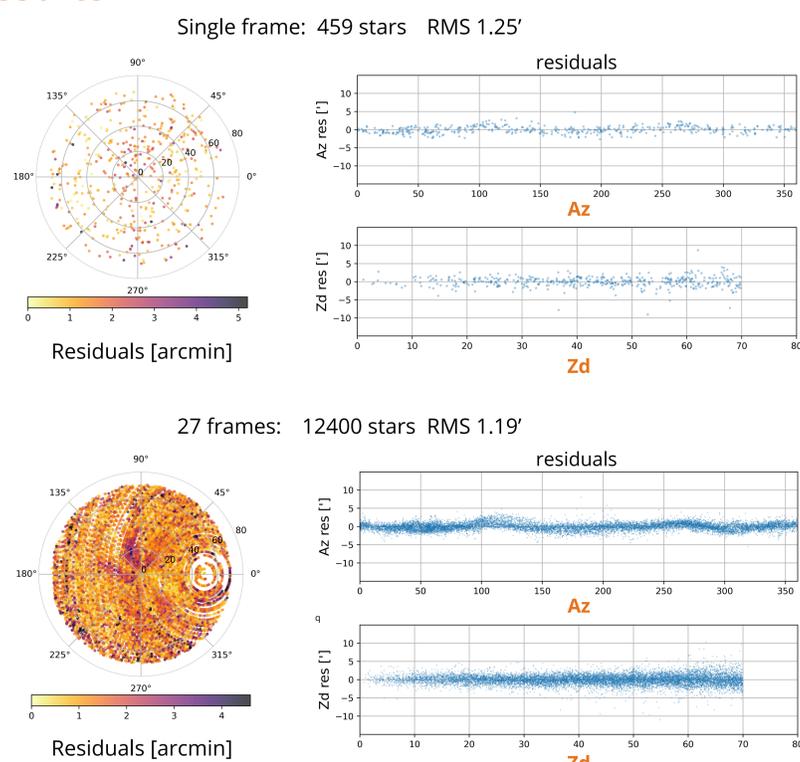
Our implementation adopts features from both models, solving for 10 parameters plus a final 2D-spline empirical correction.

Difficulties:

- Highly non-linear model
- Very sensitive to initial conditions
- Analytical Jacobian too cumbersome for practical use
- Initial parameter guesses mostly unknown

Tricky initial setup

Results

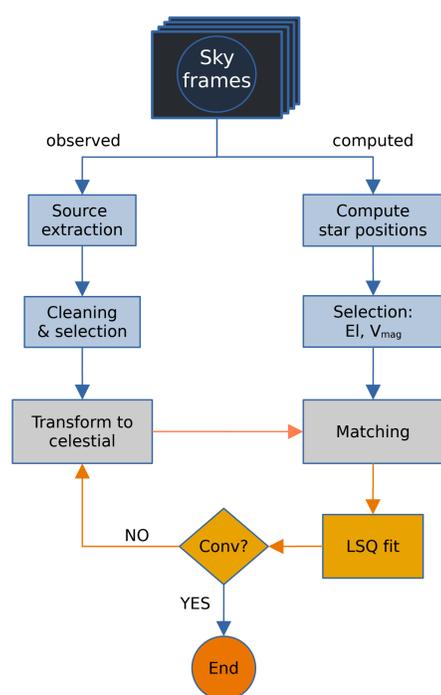


- Single 10 s expose sufficient for successful calibration
- 1 full night required for empirical correction to flatten residuals
- **Sub-pixel positional precision.** RMS 4-5 times lower than the pixel size.
- Excellent model quality maintained at low elevations

Unlocked functionality

- Pixel-perfect overlays in GUIs for operational support
- Validation of positions relayed by air safety systems (e.g. ADS-B)
- Bona fide* complementary air safety tool
- Integration in meteor sensing networks
- Sky quality monitoring, with additional photometric calibration

[1] Borovička et al. *A new positional astrometric method for all-sky cameras.* Astron. Astrophys. Suppl. Ser. 112, 173-178, 1995
[2] Barghini et al. *Astrometric calibration for all-sky cameras revisited.* Astron. Astrophys. 626, A105, 2019



Software used

- SExtractor
- Skyfield
- NumPy, SciPy, Pandas

Implementation diagram, with O/C branches, source extraction, position computation, matching, and iterative parameter estimation.

The computed model provides the transformation to celestial.